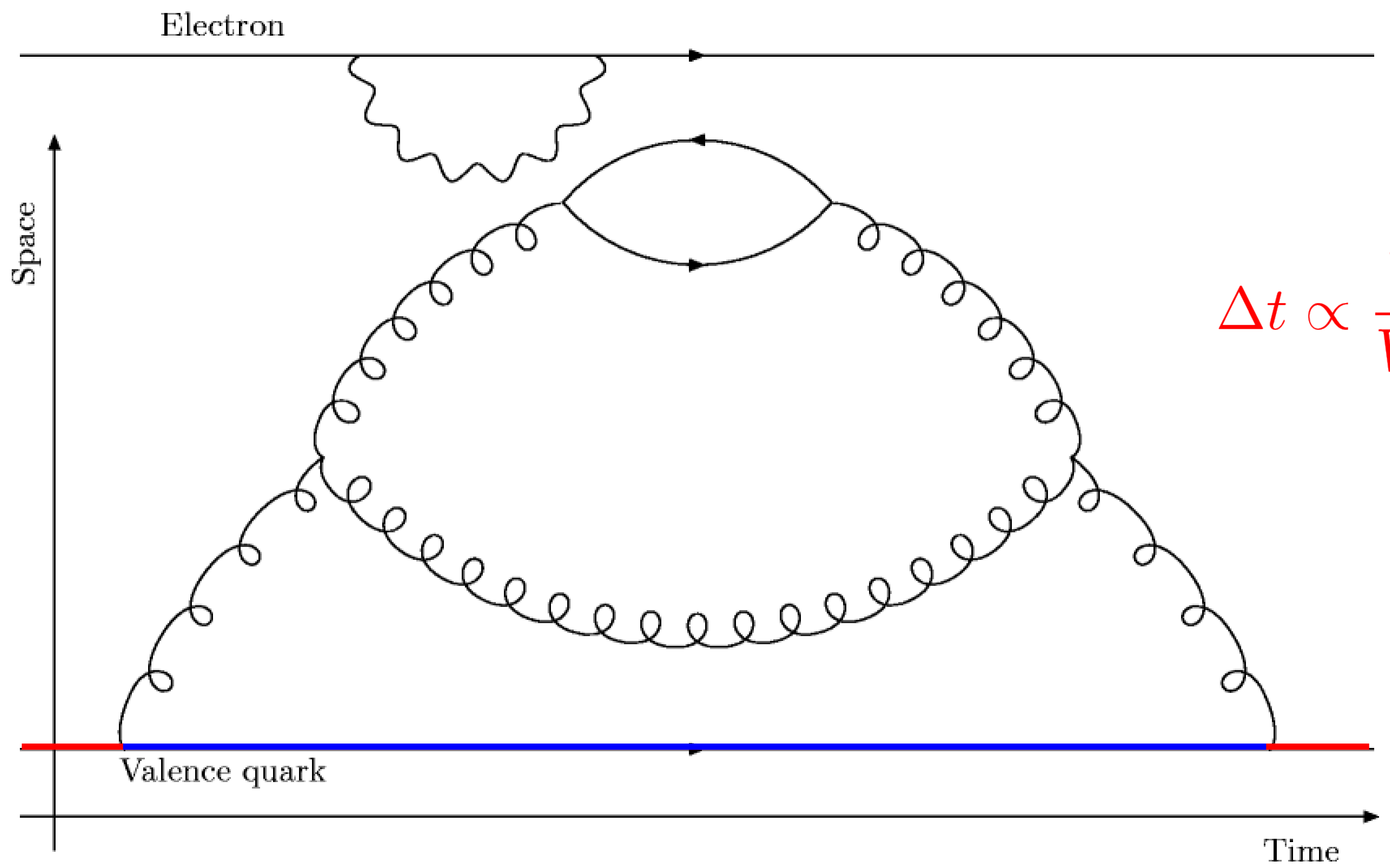
RD 2012-5 Physics Simulations: Progress report

Tobias Toll

EIC detector R&D meeting

June 5 2013

Event Generators for EIC



$$\Delta t \propto \frac{1}{V}$$

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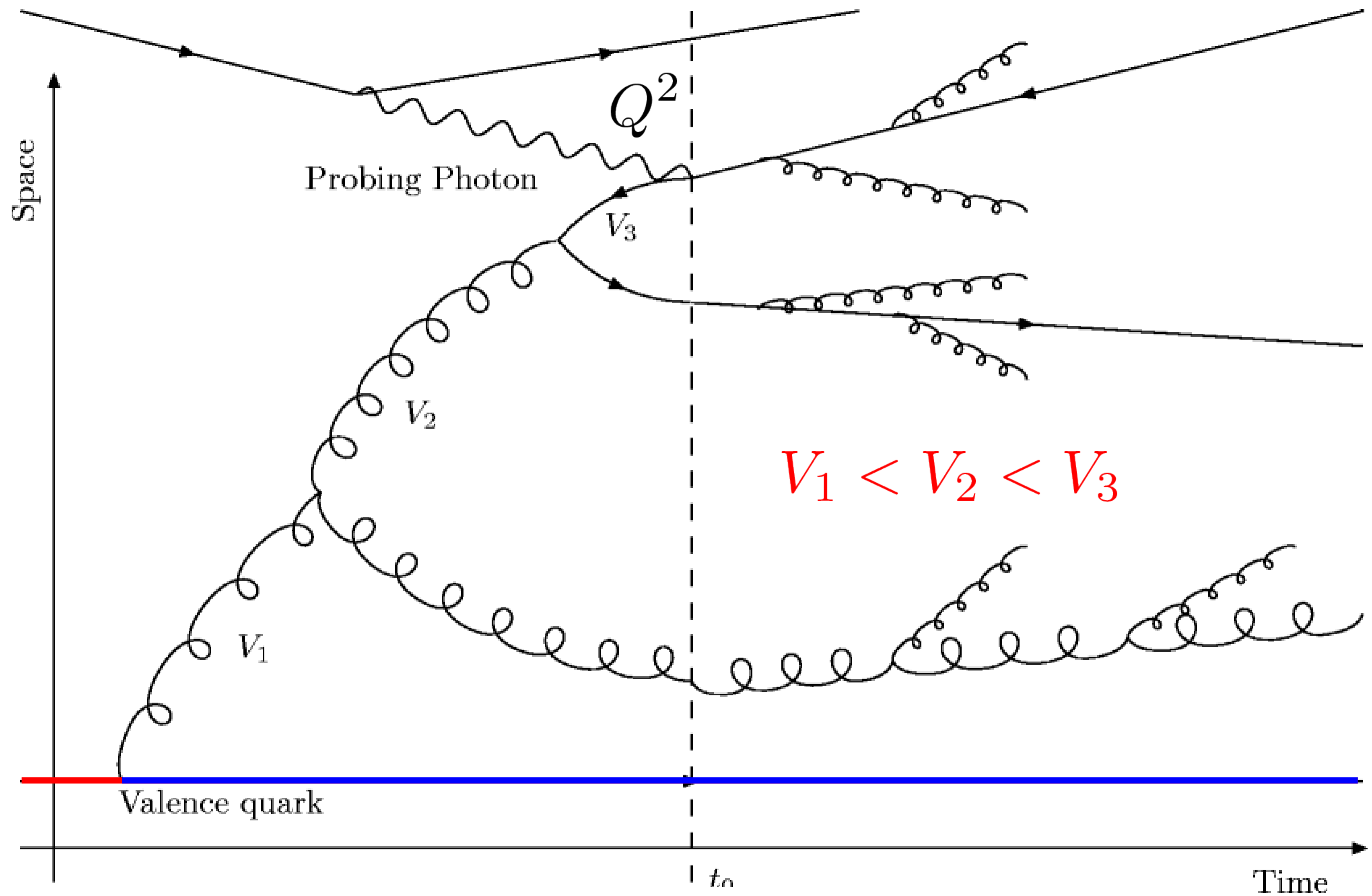
Event Generators for EIC



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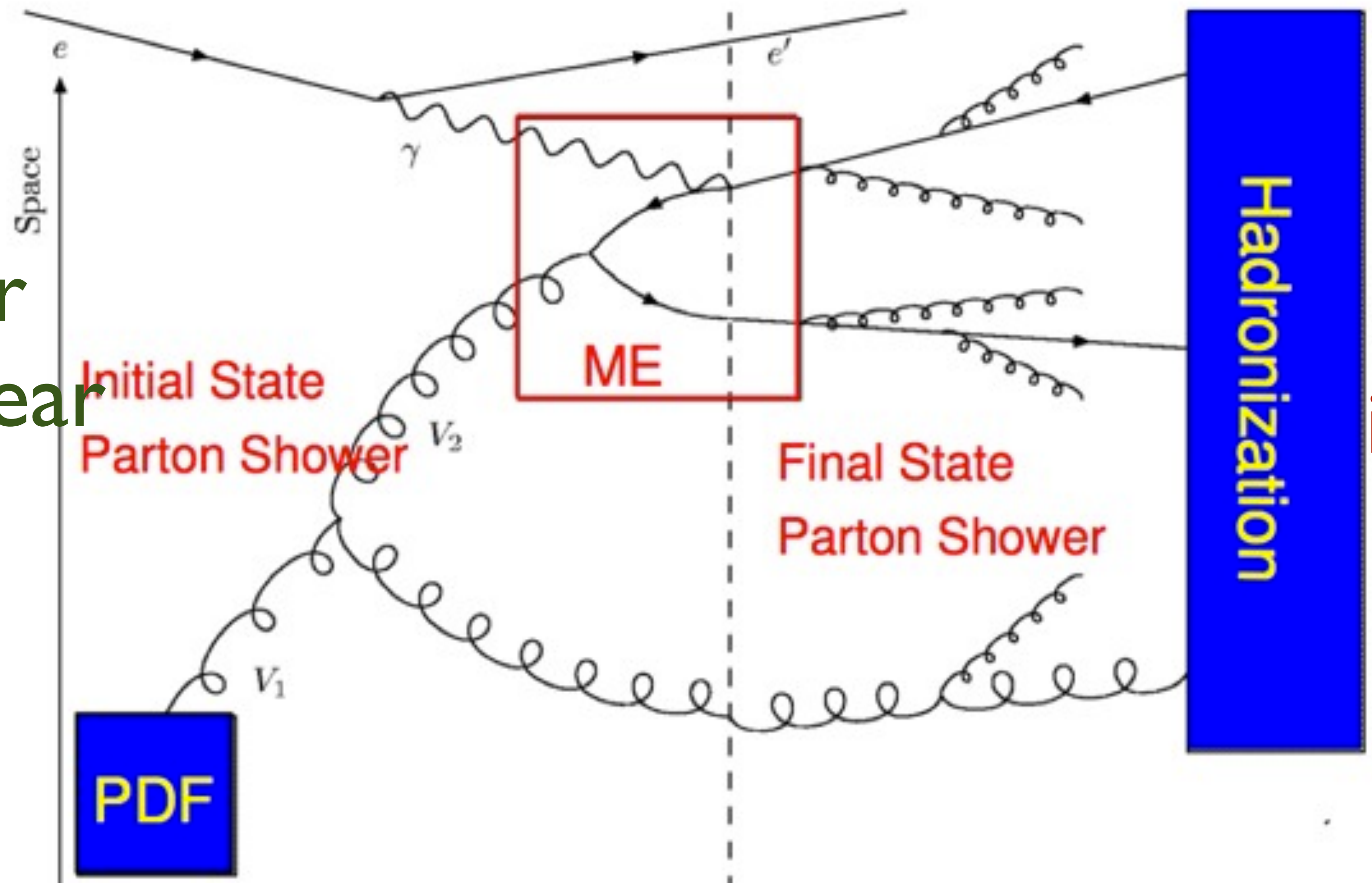
Event Generators for EIC

Hard scattering pQCD or QED Matrix Element, at LO, NLO...

Initial state QCD radiations: collinear (DGLAP), non-collinear (CCFM, RCBK) ...



Lund Strings, Clusters, independent, medium ...

Input distribution: PDF, uPDF, GPD, TMD...

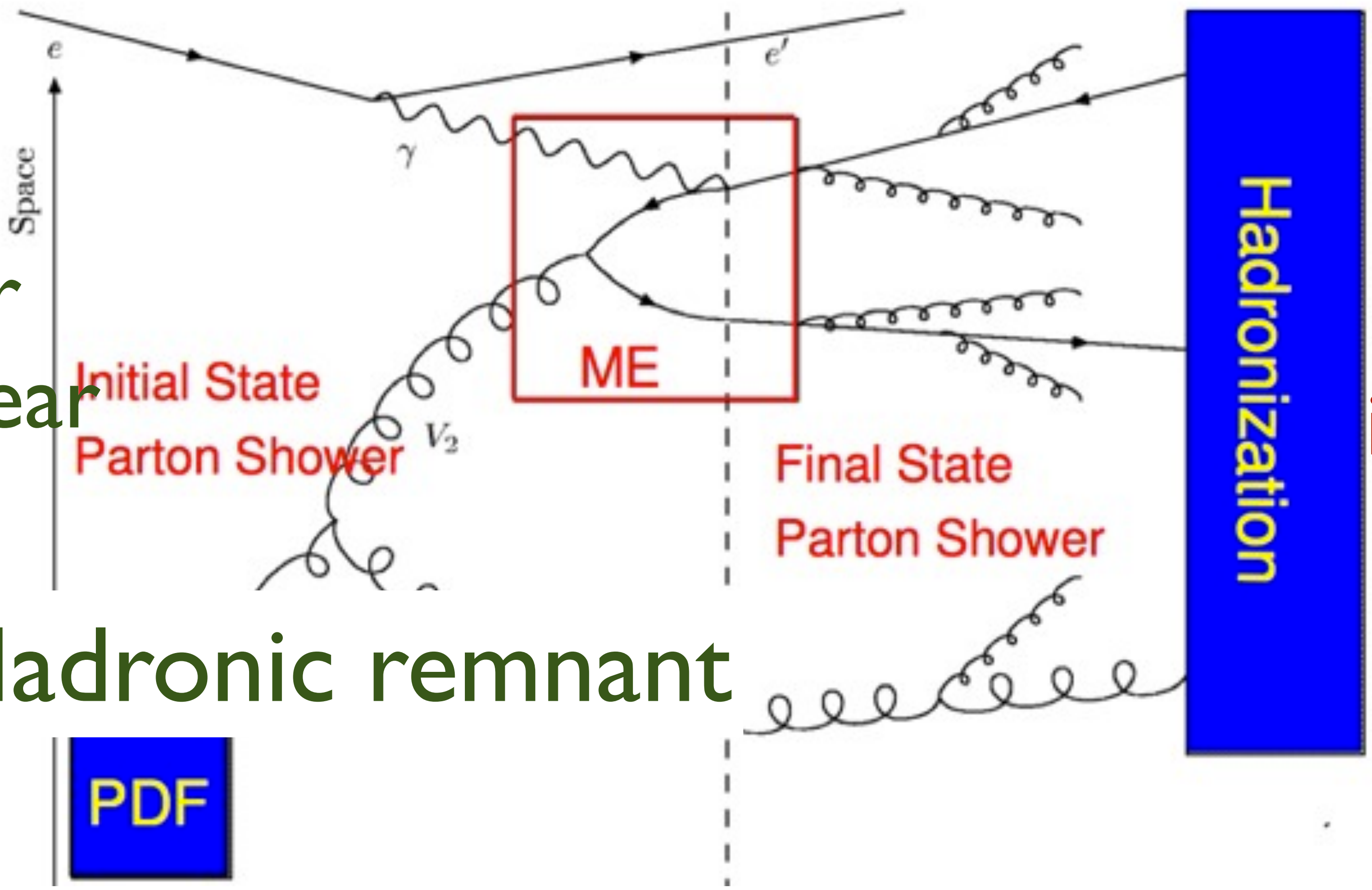
Final State brems-strahlung PS, vacuum/medium

Event Generators for EIC

Radiative corrections

Hard scattering pQCD or QED Matrix Element, at LO, NLO...

Initial state QCD radiations: collinear DGLAP), non-collinear (CCFM, RCBK) ...



Hadronic remnant

Lund Strings, Clusters, independent, medium ...

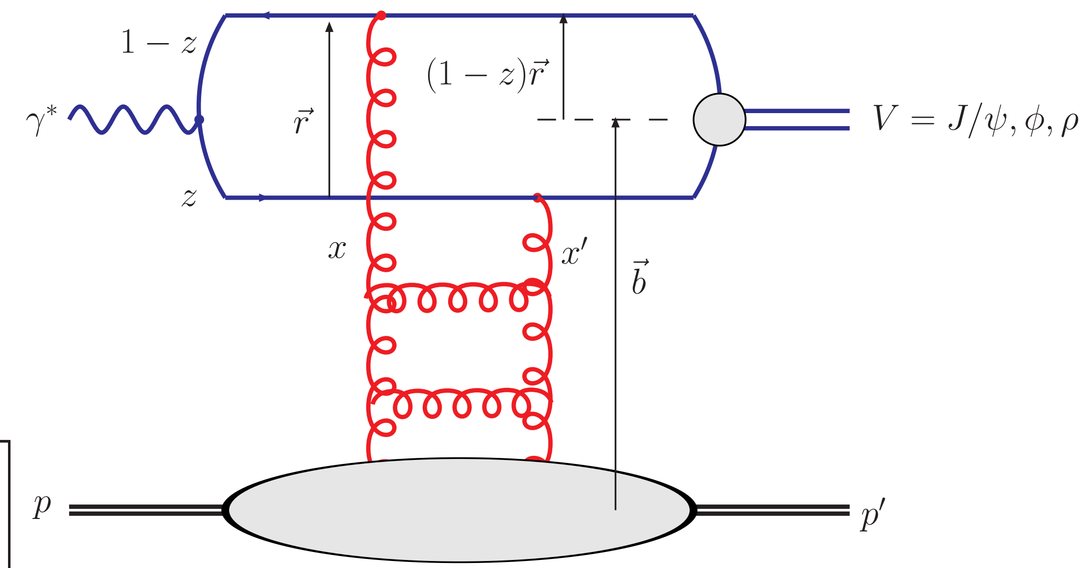
Input distribution: PDF, uPDF, GPD, TMD...

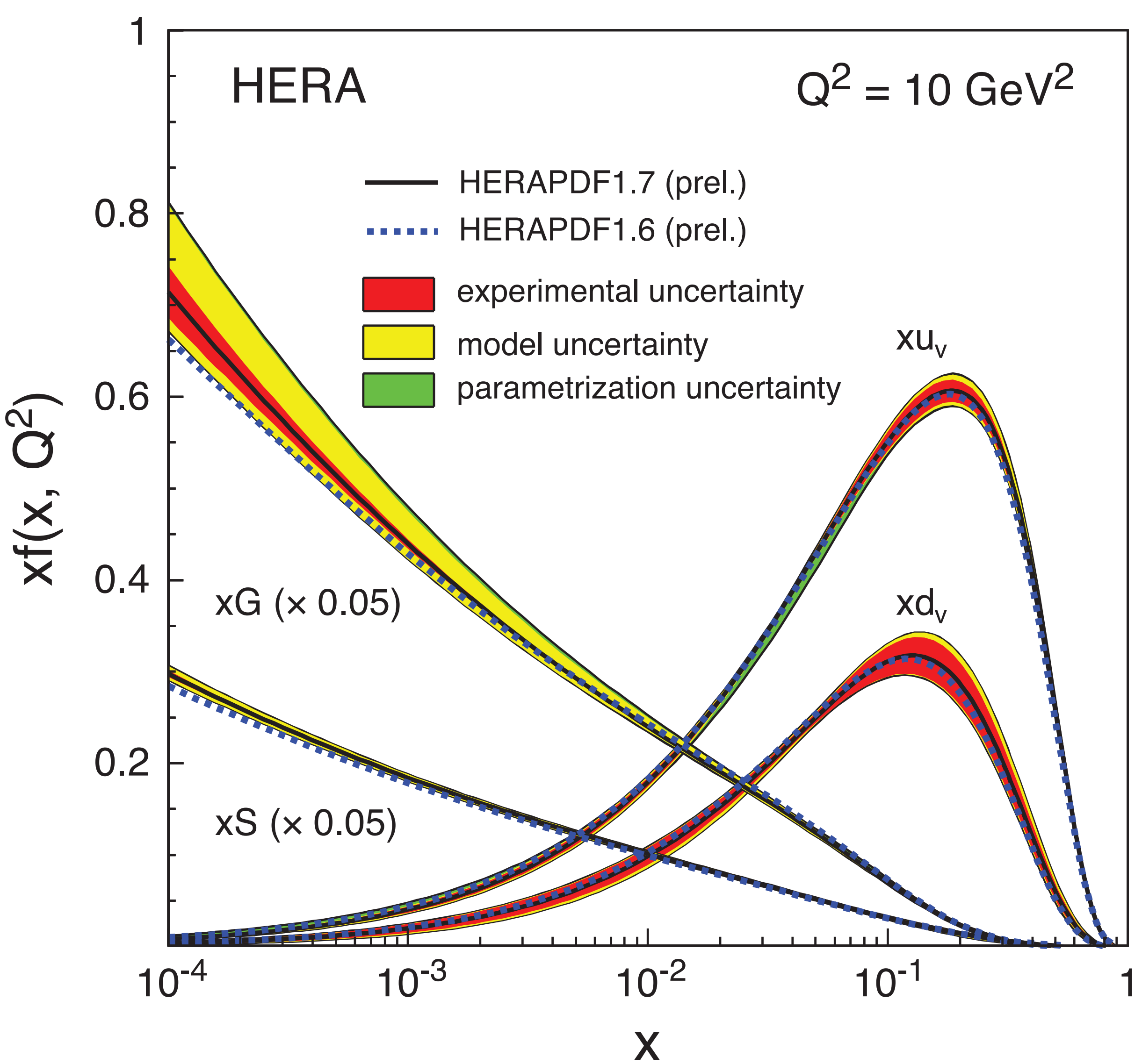
Final State brems-strahlung PS, vacuum/medium

Start with exclusive diffraction

diffraction sensitive to gluon momentum distributions²:

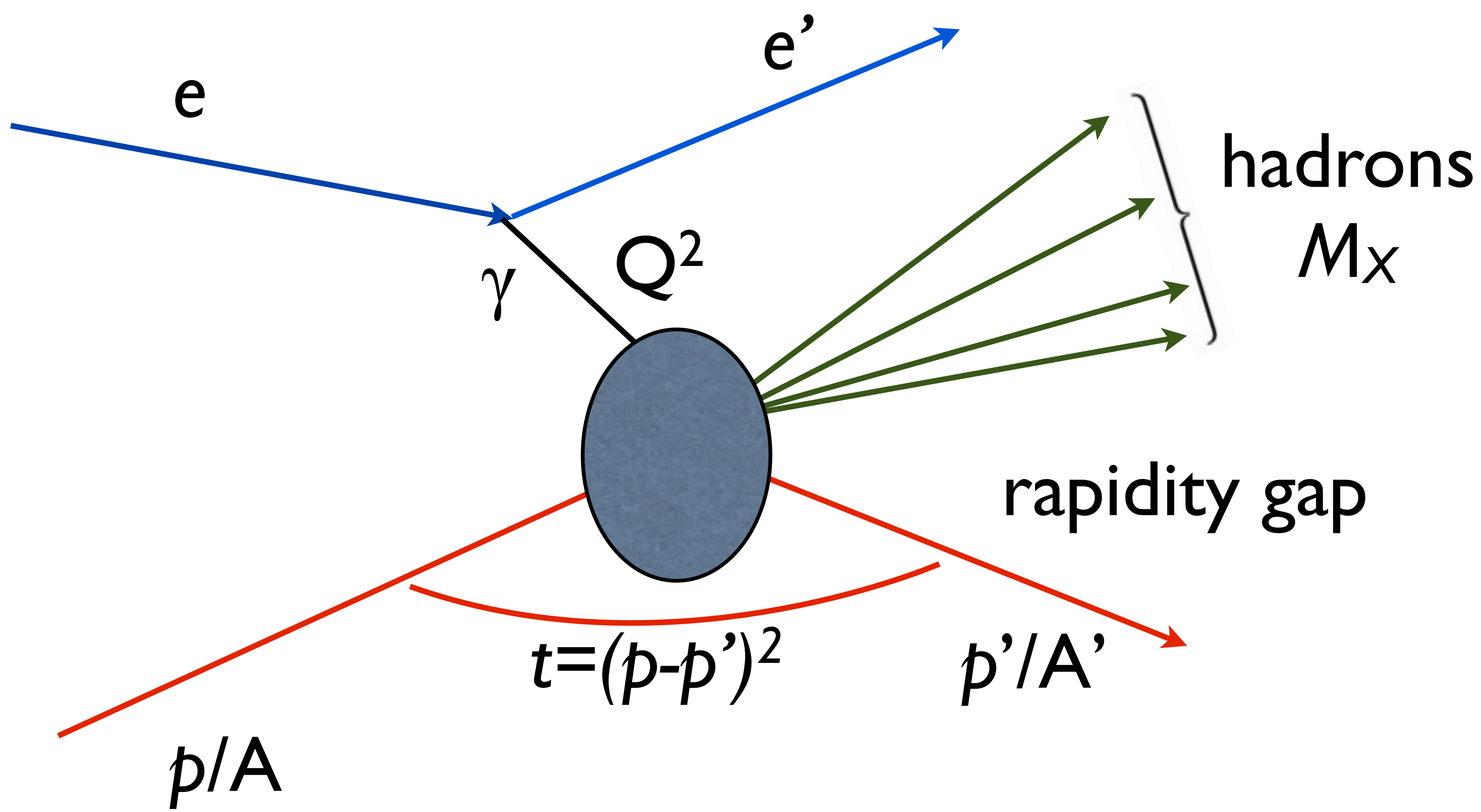
$$\sigma \propto g(x,Q^2)^2$$





how does the gluon distribution saturate at small *x*?

why is diffraction so great, part II?



depend on *t*, momentum transfer to proton/ion.

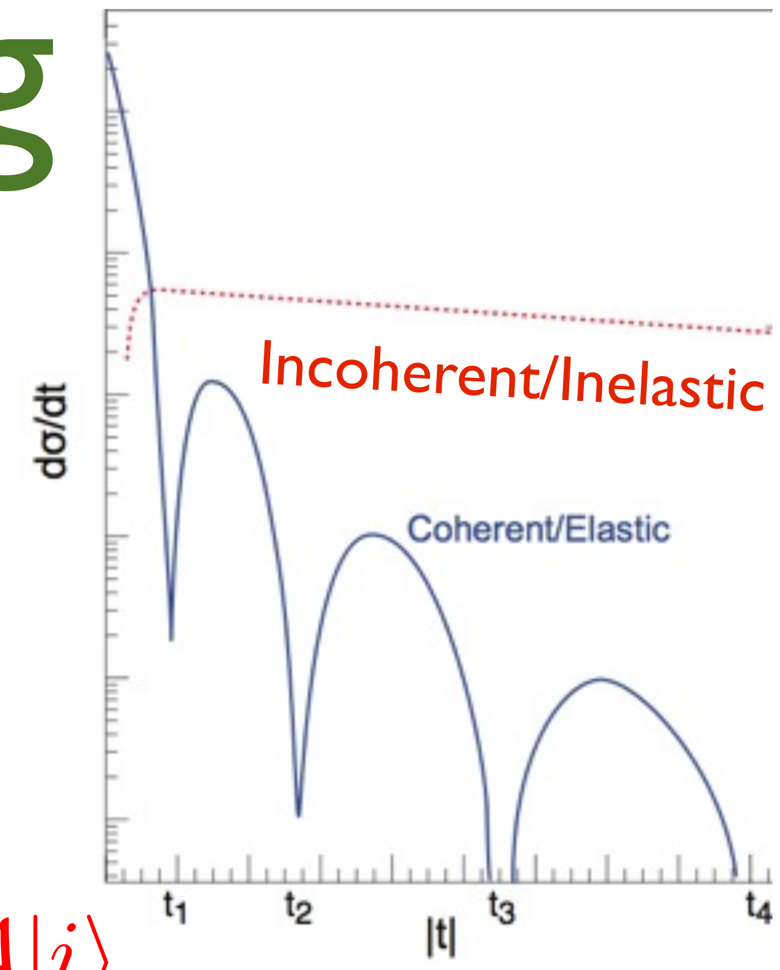
Fourier transform of t-distribution

=

transverse spatial distribution

spatial imaging!

incoherent Scattering



Good, Walker:

nucleus dissociates ($f \neq i$):

$$\sigma_{\text{incoherent}} \propto \sum_{f \neq i} \langle i|\mathcal{A}|f\rangle^\dagger \langle f|\mathcal{A}|i\rangle$$

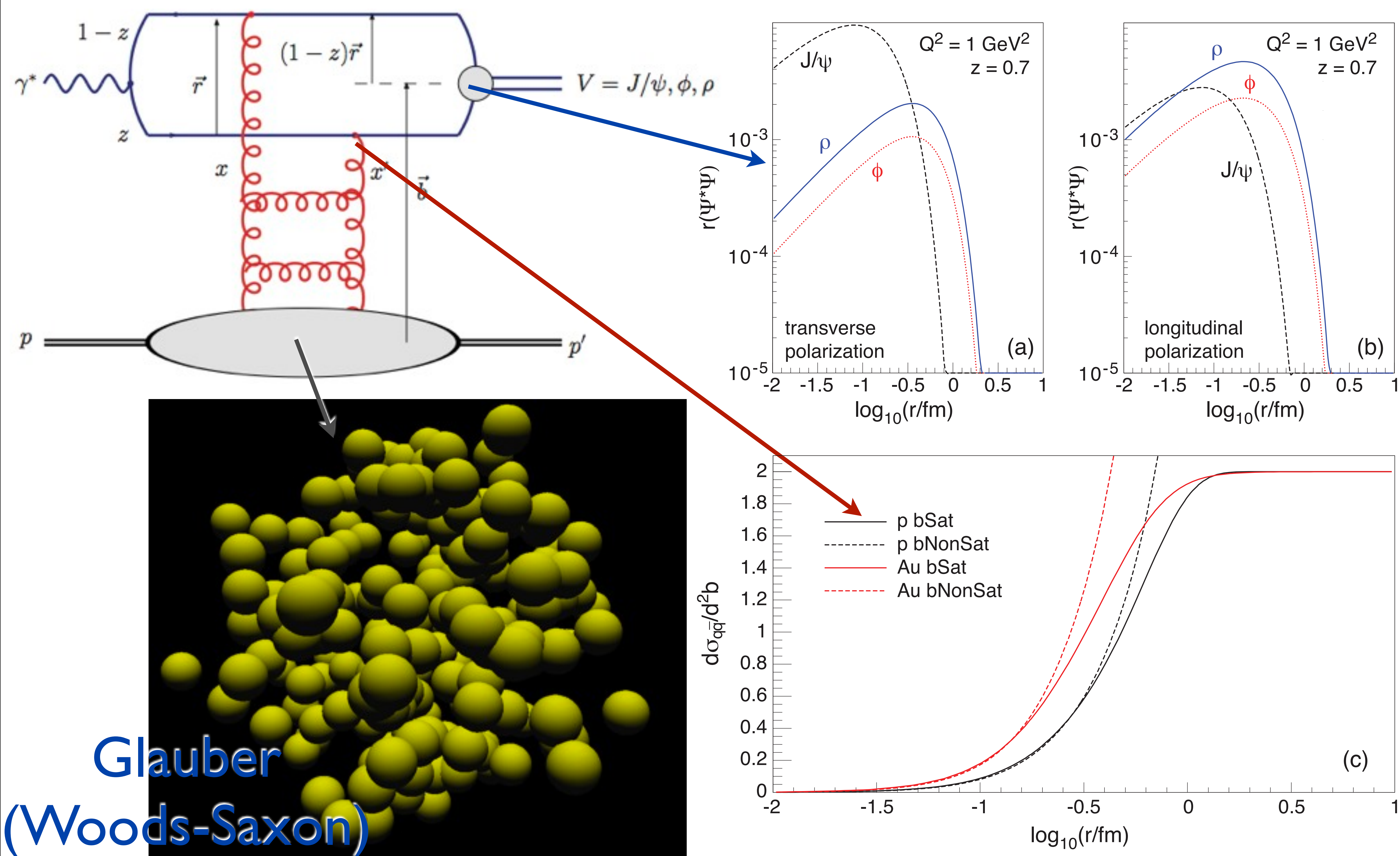
$$= \sum_f \langle i|\mathcal{A}\overbrace{|f\rangle^\dagger \langle f|}^{\text{complete set}}\mathcal{A}|i\rangle - \langle i|\mathcal{A}|i\rangle^\dagger \langle i|\mathcal{A}|i\rangle$$

$$= \left\langle i \left| |\mathcal{A}|^2 \right| i \right\rangle - |\langle i|\mathcal{A}|i\rangle|^2 = \left\langle |\mathcal{A}|^2 \right\rangle - |\langle \mathcal{A}\rangle|^2$$

the incoherent CS is the variance of the amplitude!!

$$\frac{d\sigma_{\text{total}}}{dt} = \frac{1}{16\pi}\left\langle |\mathcal{A}|^2 \right\rangle \qquad \frac{d\sigma_{\text{coherent}}}{dt} = \frac{1}{16\pi}|\langle \mathcal{A}\rangle|^2$$

EIC predictions:
Sartre dipole model with glauber bSat and bNonSat



Sartre solved technical problem

Phenomenological corrections

Include real part of amplitude:

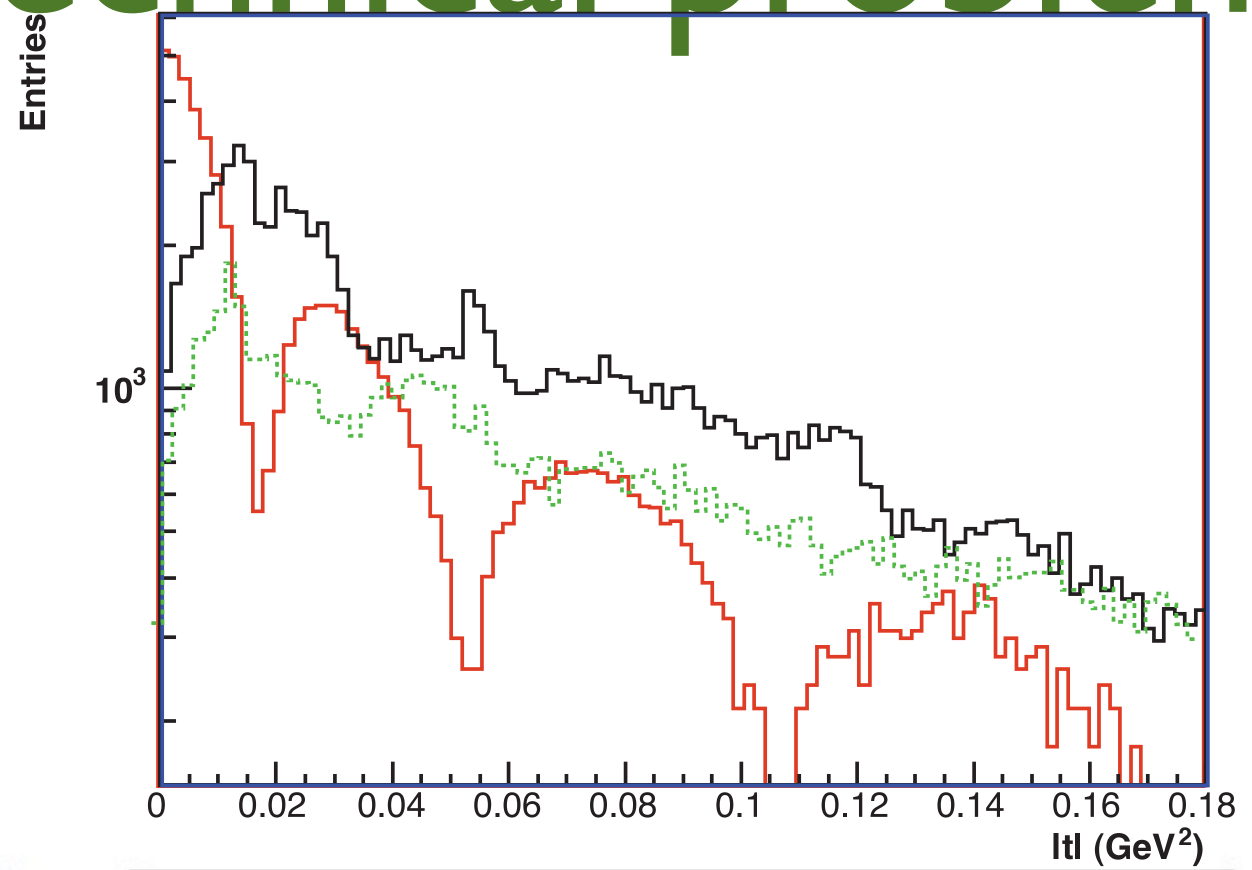
$$\beta = \tan(\pi\lambda/2) \qquad \lambda \equiv \frac{\partial \ln\left(\mathcal{A}_{T,L}^{\gamma^* p \to Ep}\right)}{\partial \ln(1/x)}$$

Include gluon "skewness": $R_g(\lambda) = \frac{2^{2\lambda+3}}{\sqrt{\pi}} \frac{\Gamma(\lambda+5/2)}{\Gamma(\lambda+4)}$

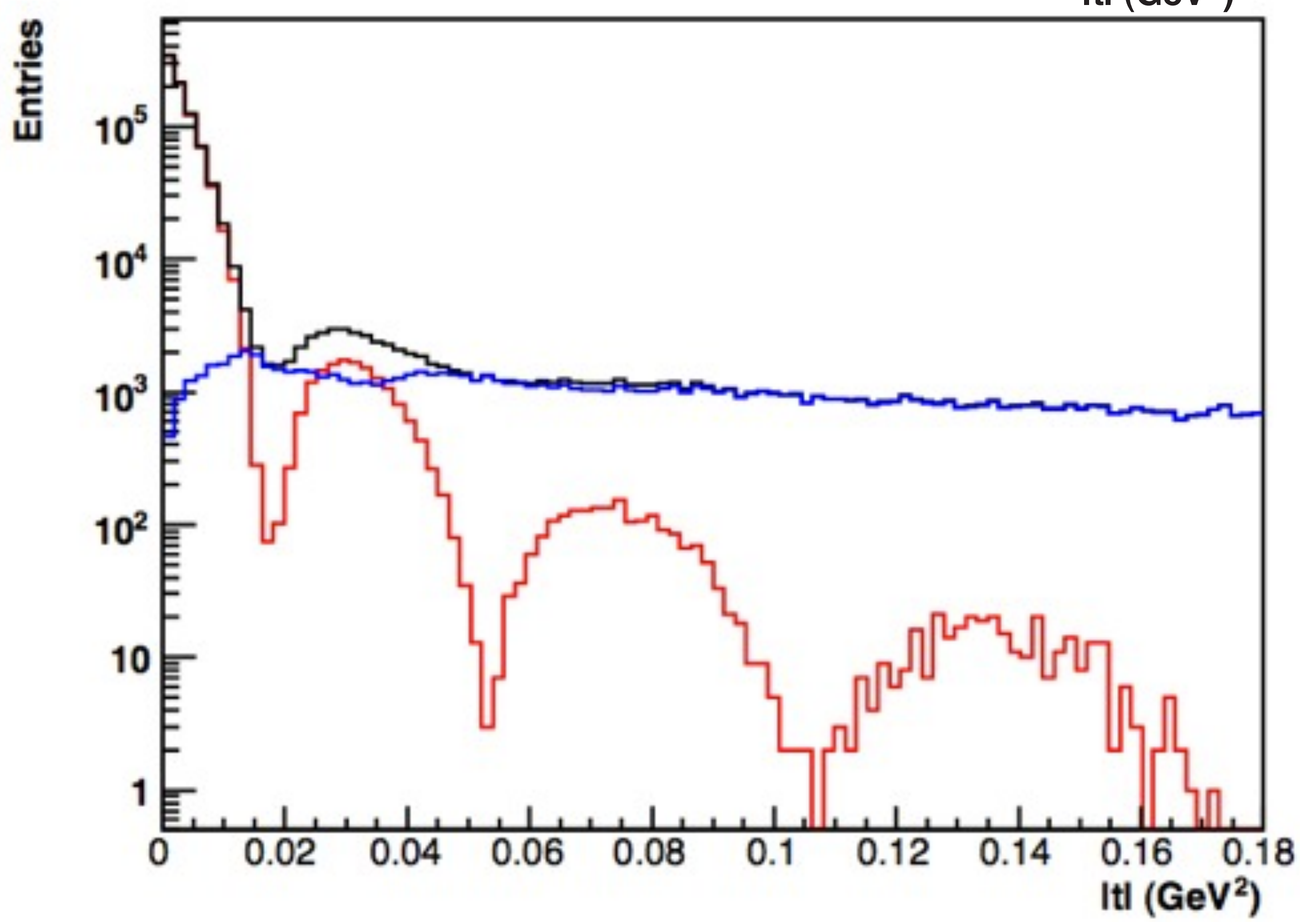
$$\frac{\mathrm{d}^3\sigma_{\text{coherent}}}{\mathrm{d}Q^2\mathrm{d}W^2\mathrm{d}t} = \sum_{T,L} \frac{R_g^2(1+\beta^2)}{16\pi} \frac{\mathrm{d}n_{T,L}^{\gamma}}{\mathrm{d}Q^2\mathrm{d}W^2} \left|\langle \mathcal{A}_{T,L}\rangle_\Omega\right|^2$$

Sartre solved technical problem

How it looked:



After intense investigations and discussions with T. Lappi:



Due to the CPU intense nature of the calculation, cross-checks are time consuming

Sar*t*re papers

Exclusive diffractive processes in electron-ion collisions, Tobias Toll, Thomas Ullrich, Phys.Rev. C87 (2013) 024913

Exclusive diffractive processes in electron-ion collisions

Tobias Toll* and Thomas Ullrich†
Brookhaven National Laboratory, Upton, NY
(Dated: February 27, 2013)

We present a new technique to calculate the cross-section for diffractive vector meson production and DVCS in electron-ion collisions based on the dipole model. The measurement of these processes can provide valuable information on non-linear QCD phenomena, such as gluon saturation, and is the the only known way to gain insight into the spatial distribution of gluons in nuclei. We present predictions of differential cross-section distribution $d\sigma/dQ^2$ and $d\sigma/dt$ for J/ψ and ϕ meson production for diffractive processes of heavy nuclei and demonstrate the feasibility of extracting the gluon source distribution of heavy nuclei, $F(b)$, from coherent diffraction. We briefly introduce a new event generator based on our method that can be used for studying exclusive diffractive processes at a future electron-ion collider.

To be submitted to Computer Physics Communications:

The dipole model Monte Carlo generator Sar*t*re 1.0

Tobias Toll[1], Thomas Ullrich[1]

Brookhaven National Laboratory, Upton, NY

Plan to publish a comprehensible study on UPC with Sar*t*re

Sartre repository

Sartre is available on an svn repository on google code:

https://code.google.com/p/sartre-mc/

Sartre **sartre-mc**

Event Generator for Exclusive Diffractive Processes in ep and eA Collisions

Project Home Downloads Source Administer

Summary People

Tip: Discuss and then document each teammate's project duties. ×

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Labels
Monte-Carlo, Event-Generator, ep-and-eA-Collisions, Diffraction, Physics, Deep-Inelastic-Scattering, Dipole-Model

Members
thomas.ullrich@bnl.gov, tobilibob

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Links

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Sartre 1.0 Online Documentation

Sartre

Sartre is an event generator for exclusive diffractive vector meson production and DVCS in ep and eA collisions based on the dipole model. It describes the process: $e\,p \to e'\,p'\,V$ and $e\,A \to e'\,A'\,V$ where $V = J/\psi, \varphi, \rho, \gamma$. Sartre is not a stand-alone program but a set of C++ classes and C functions that form the API. The heart of Sartre is an implementation of the bSat and bCGC dipole models. We extended the models to also describe eA collisions making Sartre the first generator to describe this class of processes. Saturation is introduced in the bSat model through an exponential term in the scattering amplitude. In order to study the impact of saturation on the production cross-section we also construct a non-saturated version of the bSat model, bNonSat, by linearizing the dipole cross-section.

Sartre was developed at Brookhaven National Laboratory for studies of electron-ion collisions at future facilities such as EIC (eRHIC/MEIC) and LHeC.

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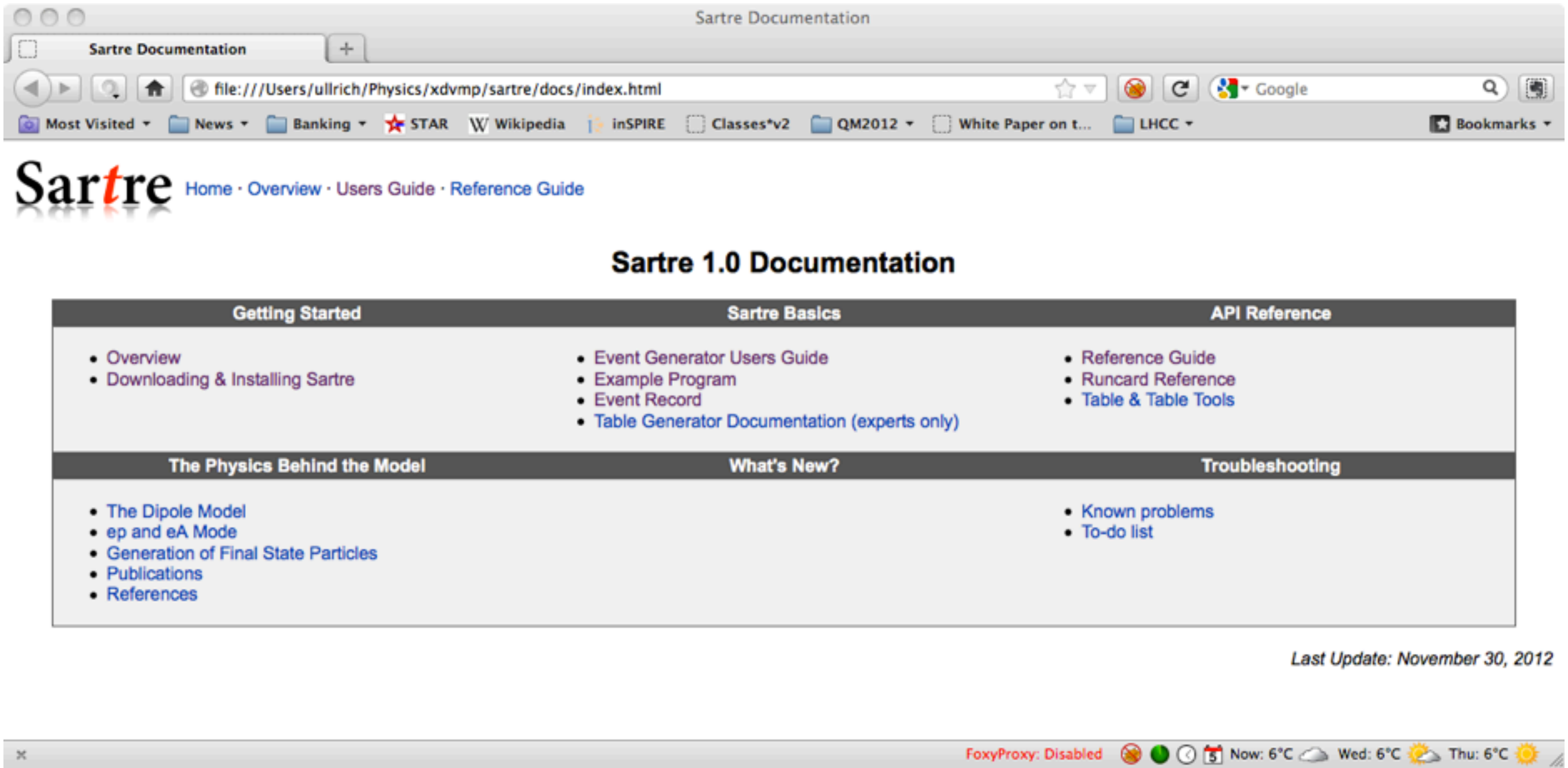
Free and unrestricted with lots of features!

Sartre on-line documentation



A pythia/DPM-JetIII hybrid

- Liang Zheng (CCNU student, located at BNL)

	DIS		Diffractive	
	saturated	non-saturated	saturated	non-saturated
exclusive	×	✓	VM & DVCS ✓	VM & DVCS ✓
	×	✓		
inclusive	×	✓	×	×
	×	✓		

Non-saturated DGLAP generator for eA

Uses Pythia

- for hard interaction
- DGLAP parton showers
- Fragmentation
- nPDFs EPS09

Uses DPM-JetIII

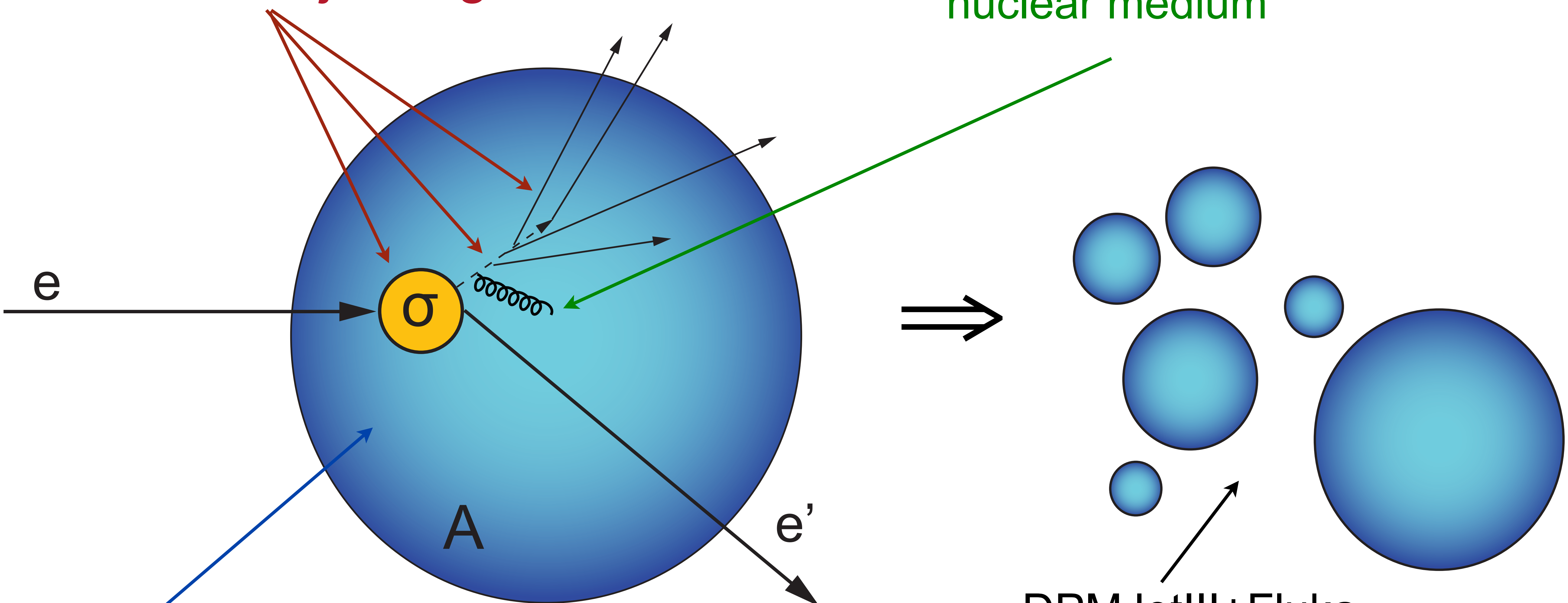
- Nuclear geometry
- Energy loss effects of hadrons in cold nuclear medium
- Nuclear break-up and evaporation with Fluka

eA-Hybrid: Implementation

PYTHIA + nPDF (EPS09)

Parton level interaction, parton shower and jet fragmentation

Salgado-Wiedemann
Energy loss effect for cold nuclear medium



DPMJetIII
Nuclear Geometry

DPMJetIII+Fluka
Nuclear Breakup &
Evaporation

Going for a non-DGLAP and/or saturated eA generator

CASCADE

CASCADE:

A very succesful *ep* and *pp* generator at HERA and LHC

Main author: Hannes Jung (DESY)

Uses CCFM evolution for parton showers.

CCFM is DGLAP-like for large x and

BFKL-like for small x.

Requiers unintegrated PDFs (uPDF)

Extending CASCADE to eA

Define uPDF: $$x\mathcal{G}(x,Q^2) \equiv \int^{Q^2} \mathrm{d}k^2 \frac{\mathcal{A}(x,k^2)}{k^2}$$

Connection to dipole model:

$$\sigma_{q\bar{q}}(r,x) = \frac{8\pi^2}{N_C}\int \frac{\mathrm{d}k}{k^3}[1 - J_0(kr)]\alpha_{\mathrm{S}}\mathcal{A}(x,k^2) = 2\int \mathrm{d}^2\mathbf{b}\mathcal{N}(x,\mathbf{r},\mathbf{b})$$

uPDF from Scattering Amplitude:

$$\frac{\mathcal{A}(x,k^2)}{k^2} = \frac{C_F}{2\pi\alpha_{\mathrm{S}}(k)k^2}\int \mathrm{d}r\mathrm{d}bJ_0(rk)\left(\frac{1}{r}\frac{\partial\mathcal{N}(x,r,b)}{\partial r} + \frac{\partial^2\mathcal{N}(x,r,b)}{\partial r^2}\right)$$

Building ion scattering amplitude:

$$1 - \mathcal{N}^{(A)} = \prod_{i=1}^{A}\left(1 - \mathcal{N}^{(p)}(x,r,|\mathbf{b}-\mathbf{b}_i|)\right)$$ This we do in Sartre!

NEED: b-dependent proton scattering amplitude that can be combined with the CCFM ecolution AND describes HERA F_2 data well AND can with an anylitcally written starting distr.

Extending CASCADE to eA

NEED: b-dependent proton scattering amplitude that can be combined with the CCFM ecolution AND describes HERA F_2 data well AND can with an anylitcally written starting distr.

Only option Golec-Biernat Wüsthoff (GBW) model, a simple ansatz for the dipole model.

$$\mathcal{N}(x,r) = \sigma_0 \left(1 - e^{-Q_s^2(x) r^2}\right)$$

$$Q_s^2 = \left(\frac{x_0}{x}\right)^{\lambda}$$

b-dependence is a Θ-function: $T_p(b) = \Theta(R_p - b) \Rightarrow \sigma_0 = \pi R_p^2$

Building ion scattering amplitude:

$$1 - \mathcal{N}^{(A)} = \prod_{i=1}^{A} \left(1 - \mathcal{N}^{(p)}(x, r, |\mathbf{b} - \mathbf{b}_i|)\right)$$

This we do in Sartre!

Extending CASCADE to eA

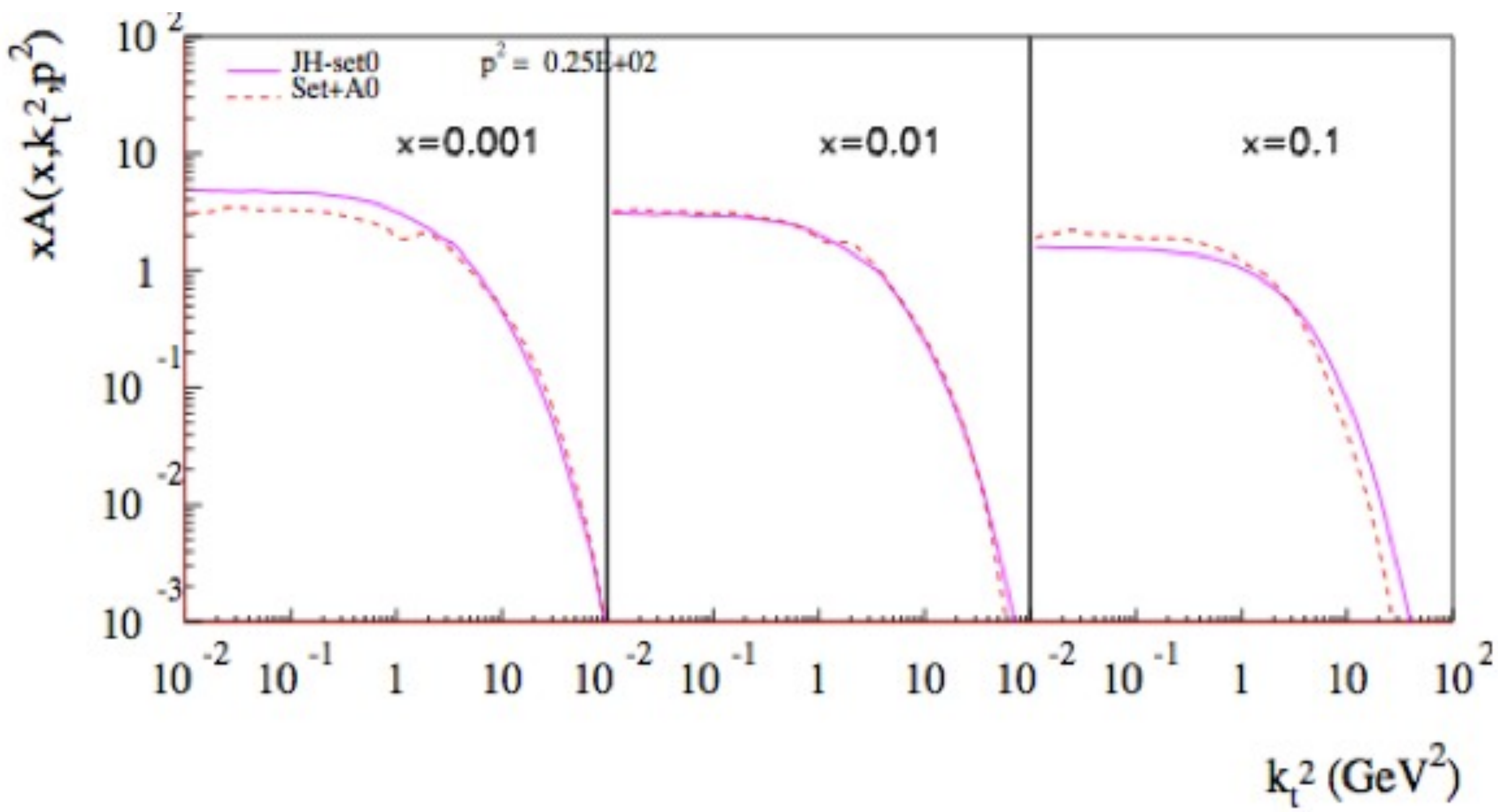
Scheme:

1) Fit the GBW model to HERA F_2 data with HERA-fitter
   Waiting for H. Jung to integrate CASCADE into HERA-fitter (next days)
2) Construct the nuclear scattering amplitude from the resulting fit.
3) Construct the nuclear uPDF

Projected time-scale: a few weeks

Extending CASCADE to eA

What effect would a saturation boundary in the evolution have on the fit?



Stop the evolution if k_t becomes smaller than Q_s (with possible damping)

$$Q_s^2 = \left(\frac{x_0}{x}\right)^{\lambda}$$

Early work by K. Kutak and H. Jung

study never completed, can be further investigated now.

Extending CASCADE to eA

Integrate CASCADE into the framwork of the DPMJetIII hybrid:

Uses CASCADE

- for hard interaction
- CCFM parton showers
- Fragmentation
- Nuclear uPDFs
- Possible saturation bound in shower

Uses DPM-JetIII

- Nuclear geometry
- Energy loss effects of hadrons in cold nuclear medium
- Nuclear break-up and evaporation with Fluka

Summary and outlook eA

Exclusive diffraction:

Unique qualities in eA: coherent and incoh. distr.
Sartre finished and documented
Papers: 1 published, 1 to be submitted within a few days.
Planned: Extensive UPC studies compared to new LHC
Outlook: Extending to coherent inclusive diffraction

eA hybrid:

Includes a set of realistic nuclear effects
Non-saturated DGLAP only

CASCADE:

All is set, ready to start.
non-DGLAP (CCFM) evolution
saturation in initial state, and possible in evolution

Summary ep generators

Radiative corrections added to Pythia and Lepto by E. Aschenauer

LEPTO now with azimuthal asymmetry to all orders in k_t/Q
-- PEPSI obsolete
M.D. Baker

MILOU updated and maintained by S. Fazio